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CERAMIC TBS/POROUS METAL COMPLIANT LAYER

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INTRODUCTION

- Technetics Corporation manufactures metal fiber materials and components used in aerospace applications.
- Our technology base is fiber metal porous sheet material made from sinter bonded metal fibers.
- Fiber metals have % densities (metal content by volume) from 10 to 65%.

FIBER METAL MATERIALS

- Fiber metals have distinct controllable properties including porosity, pore size, tensile strength and mechanical properties, permeability, thermal conductivity, electrical resistance and weight.
- Properties are controlled through choice of product alloy, % density, thickness, fiber diameter and sintering parameters.
- Fiber metals are tailored to a defined set of properties.

COMPLIANT LAYER TBCs

- One application for fiber metals materials is as a compliant interlayer for ceramic thermal barrier coating systems.
- The fiber metal compliant layer, which we call pad, is brazed to the metal substrate.
- The ceramic coating, typically 8% yttria stabilized zirconia, is plasma flame sprayed (PFS) onto the pad after depositing a NiCrAlY bond coat to roughen the pad surface.

- The ceramic coating has also been applied by direct bonding monolithic ceramics to the pad and by sintering Sol-Gel powder to the pad.

- The pad interlayer partly decouples the ceramic coating from the metal backing.

- The ceramic-pad approach allows .060-.100" thick PFS coatings that survive cyclic thermal shock in gas turbine engines. Coating thickness "limits" have not been fully explored.

PAD PROPERTIES

- Sinter bonded fiber structure.

- Supplied densities: 10% - 65% of solid alloy.

- Alloys supplied: Hoskins 875 (FeCrAlY), 347ss.

- Fiber diameters: .0056" and .004"

- Typical thickness: .020-.250"

- Oxidation life of Hoskins 875 Pad (7% wt. gain): 10,000 hrs. @ 1800°F.

- Shapes available: flat sheet, or 3D shapes by custom order.

- Pad properties in plane at 35% density:

    - UTS - RT/1500°F
      4800/1000 PSI

    - MOE - RT/1500°F
      1.4/.26 MILLION PSI

    - Thermal conductivity RT/1500°F 8.5/21 (BTU-IN/HR-FT^2—°F)

    - Pad is low modulus, a good insulator, porous and with oxidation capability to 1800°F. The thermal conductivity of the pad is similar to that of the zirconia ceramic coating.

CERAMIC/PAD TBC DESIGN

- Considerations we believe to be important in using pad as a ceramic coating interlayer are:

  --the low modulus compliance of the pad.

--the insulating capability of the pad which retards heat relaxation of the backing during PFS and thermal cycling.

--the formation of a low residual stress ceramic coating on the compliant pad.

- In designing a ceramic-pad TBC coating, the following constraints must be considered:

    1) The expansion match of ceramic and pad with the backing

    2) The geometry of the hardware

    3) The desired thermal benefit influenced by thermal conductivities, thickness, composition and porosity of the coating

    4) Operating environment

    5) Pad properties

    6) PFS parameters

THERMAL SHOCK RIG

- Design concepts are evaluated on 1 x 3" coupons on a thermal shock rig.

- The rig is designed to simulate the rapid temperature excursions seen in gas turbine engines.

- About 1.5 million thermal shock cycles have been accumulated on our rig to provide a database on coating system performance.

- The rig consists of a station with one 3100°F propane/oxygen/air torch and two cold air jets.

- Two samples are run at each station, one in the torch flame and one at a cold air jet. The sample face cycles between torch and cold air jet in 5-7 seconds.

- The sample backside is continuously cooled by two air jets. The sample TBC face cycles between 2500°F and 200°F. A 90 second cycle is used to insure steady state conditions at each position.

- Samples are cycled 5000 times or to failure if that occurs first. Failures typically occur at less than 100, 2500 OR 4000 cycles.

- The current rig configuration has 18 stations which can cycle 36 samples at one time.

FABRICATION

- Pad is brazed to the metal substrate using superalloy braze alloys such as AMS 4777 using expansion fixturing.

- Backing and pad processing is designed to weld, machine and anneal hardware before coating application to remove residual stress.

- PFS coatings are applied using robotic gun positioning to insure reproducibility of the multi-layer coating.

APPLICATIONS

- The primary application of this system has been in the hot sections of gas turbine engines.

- Compliant layer ceramic TBCs are currently used in rub tolerant turbine seal systems for gas turbine engines. These .060" ceramic, .060" thick pad systems provide rub tolerance and erosion resistance coupled with substantial system insulating capability to contain and utilize heat in the turbine section. To date, a limited number of production engines use ceramic-pad TBC systems.

- Ceramic-pad TBCs have also been developed for thermal protection of high temperature combustors. A "composite matrix" approach was developed (Ref. 1). In this approach, a tiled ceramic was employed on a continuous compliant pad interlayer/sheet metal backing. Low flow cooling of the pad was accomplished by through pad air flow. The concept has successfully tested to 2500°F gas temperatures, with further testing to 3000°F planned.

- The compliant matrix combustor was fabricated as three ceramic-pad TBC sections: outer liner and inner liner (cylindrical), outer transition (complex half bagel shape). The pad-backing was produced as flat sheet stock. The outer and inner liners were roll formed and welded to produce the pad-backing cylinders. The transition was hydroformed. The zirconia ceramic tiles were formed in place during plasma spraying. Tile slots were formed via shadowing by the spray masking grid.

- Ceramic coated porous core vanes have also been investigated (Ref. 2). This approach utilized the cooling distribution characteristics of the porous compliant core as a ceramic TBC support.

- A number of non-compliant layer TBCs have been investigated. These coatings utilize the bond coat, stress distribution and substrate cooling methods learned in developing ceramic-pad systems. Ceramic TBCs have been directly applied to substrates including stainless steels, superalloys, cast iron, aluminum, titanium, silicon carbide, silicon nitride, and carbon matrix composites.

SUMMARY

- Ceramic-compliant layer TBCs offer a means of applying a relatively thick TBC system with good heat insulating qualities.
- The ceramic-pad TBC is produced by brazing pad to a metal backing and applying the TBC by plasma spraying.
- Ceramic/pad TBCs have proven to be durable in gas turbine engines surviving rapid thermal excursion, vibrations, mechanical loading, high temperatures, gas erosion and rotating blade/ceramic interaction.
- Enhanced thermal protection of the substrate is possible using low air flow rates through the compliant pad.

REFERENCES

1. "Composite Matrix Cooling Scheme for Small Gas Turbine Combustors", M. Paskin, W. Acosta et al, AIAA 90-2158, July 1990.

2. "Small Gas Turbine Combustor Study - Compliant Metal/ Ceramic Liner Performance Evaluation", W. Acosta, C. Mongren, AIAA 86-1452, June 1986.

3. "Gas Turbine Ceramic-Coated Vane Concept with Convection-Cooled Porous Metal Core", A. Kascak, C. Liebert et al, NASA TP 1942, AVRADCOM TR 81-C7, December 1981.

4. "Strain Isolated Ceramic Coatings for Gas Turbine Engines", R. Tolokan, G. Jarrabet, J. Brady, ASME 85-GT-96, March 1985.

5. "Metal Fiber Based Clearance Control Seals for Gas Turbine Engines", R. Tolokan, G. Jarrabet, H. Howe, ISROMAC-4, April 1992

Figure 1

Zirconia - Compliant Layer - Backing Cross Section

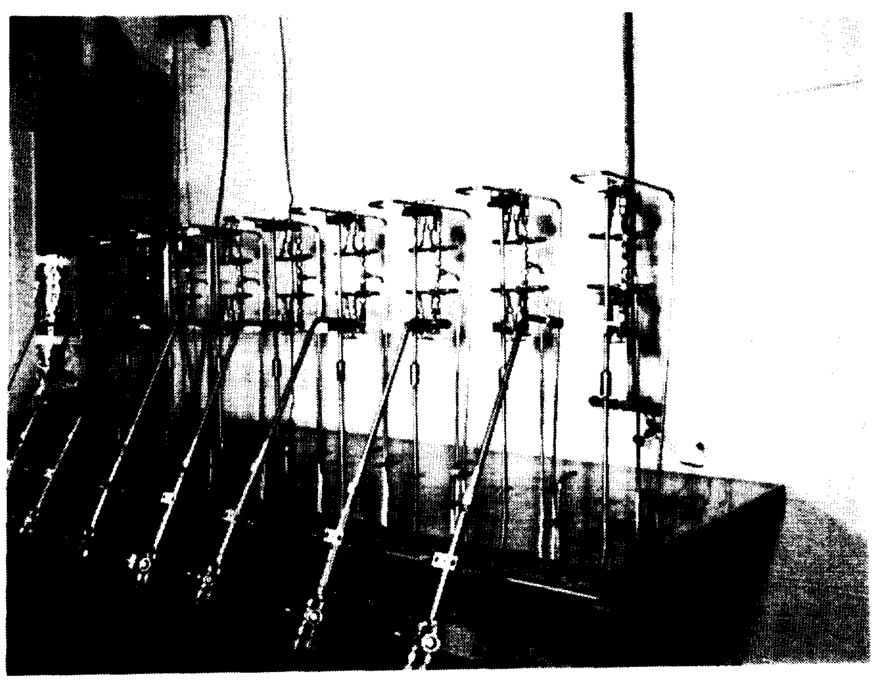

Figure 2

Eight Torch Thermal Shock Rig

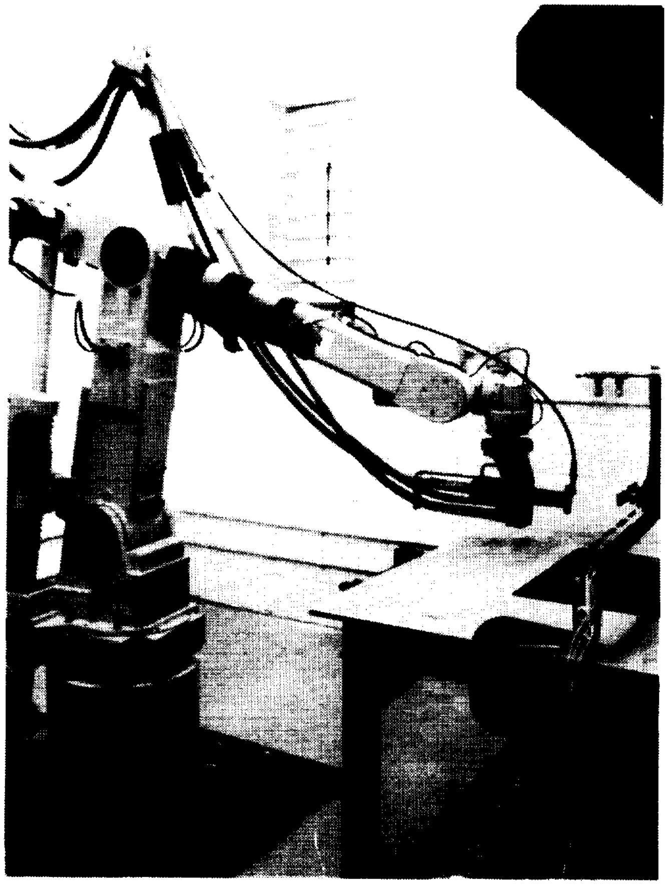

Figure 3

CNC Robotic Plasma Spray Gun Positioning

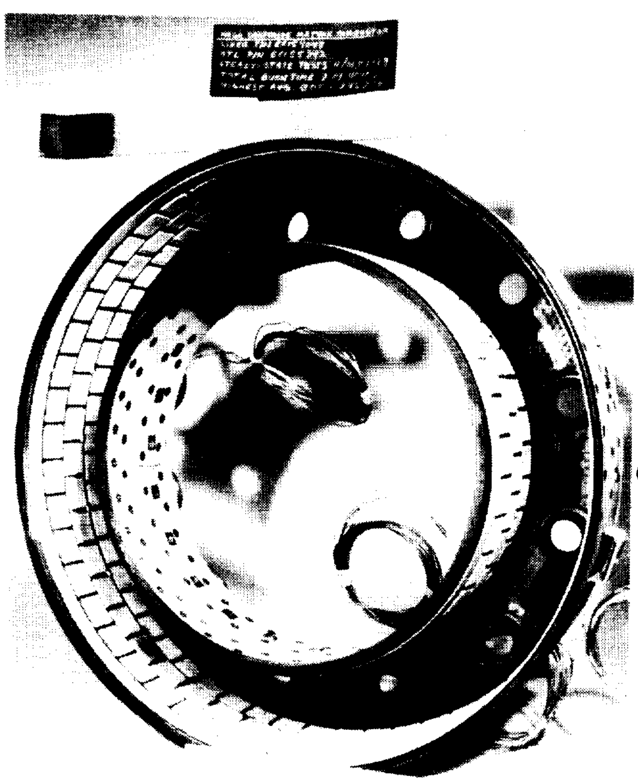

Figure 4

Army-NASA Tiled Compliant Matrix Combustor